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Crustal stress-field in Greece and implications on faulting mechanisms

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Greece is widely recognized as one of the most rapidly deforming regions in the world. Significantly large strain-rates are observed along the Hellenic Arc, owing to the active subduction of the eastern Mediterranean lithosphere beneath the Aegean, but also in the North Aegean Trough, caused by the westwards propagation of the North Anatolian Fault. In the framework of the HELPOS project, we collected a massive dataset of over 1900 focal mechanisms (Kapetanidis & Kassaras, 2019a) of $M_w \geq 3.5$ earthquakes that have occurred at focal depths of $Z \leq 30$ km to resolve the stress-field in a grid with node-spacing 0.25°, covering the entire region of Greece, using a damped least-squares inversion (Hardebeck & Michael, 2006). We then investigated the properties of the stress-field in terms of its principal stress axes orientations and stress-ratio to determine the main tectonic features across the Greek territory.

The resulting stress-field is presented in Fig. 1a, interpolated in regions with insufficient data, such as the southern Aegean and the respective part of the volcanic arc, which are generally characterized by very low seismicity. NW Greece and Corfu Island are mainly affected by NE-SW contraction, favoring NW-SE reverse faulting and, in addition, strike-slip faulting, mainly in Epirus. Northern/central Greece and the Corinth Rift are primarily characterized by E-W normal faulting (Fig. 1b). Central Aegean, including Lesvos (e.g. Papadimitriou et al., 2018), Chios and Samos islands, is mainly governed by SW-NE dextral strike-slip faulting but also N-S extension (transtensional tectonics), with a very stable minimum principal stress axis (**S**$_3$) in northern Aegean, also producing E-W normal faulting which becomes dominant near Dodecanese. The southern part of the Hellenic Arc around Crete is dominated by SW-NE sinistral strike-slip faulting with the presence of E-W reverse faulting, in the vicinity of the subduction zone. In W. Greece (e.g. Kassaras et al., 2016), SW-NE dextral strike-slip dominates along the Cephalonia-Lefkada Transform Fault Zone.

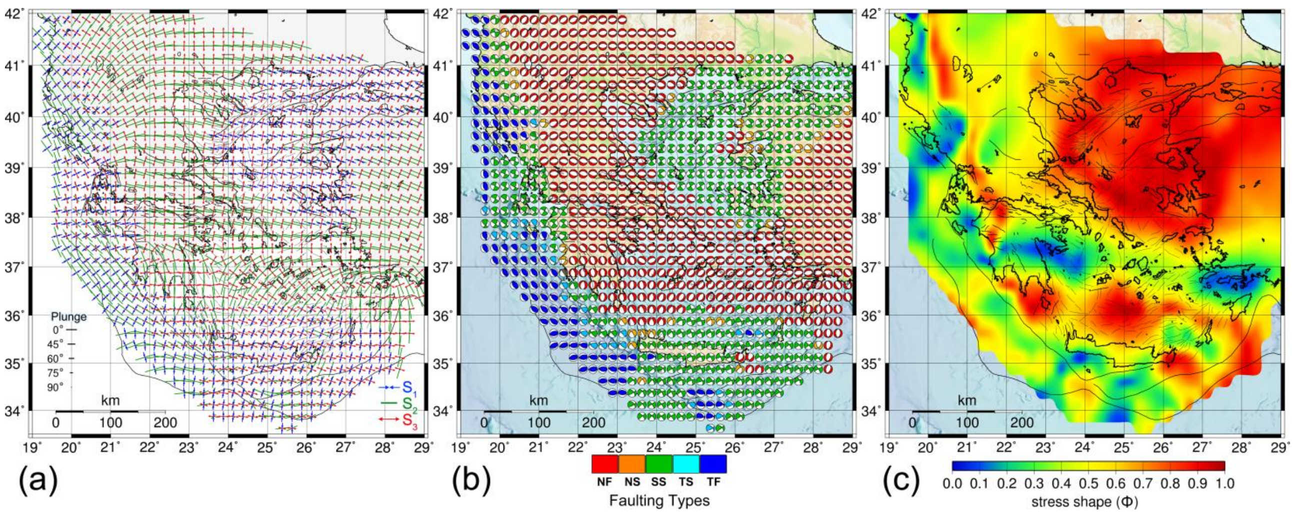

Figure 1. a) Principal stress axes S$_1$, S$_2$, and S$_3$ of the resolved stress-field, b) Expected faulting types for faults optimally oriented to the stress-field (NF/SS/TF: Normal/Strike-Slip/Thrust faulting, NS/TS: Oblique-Normal/Thrust faulting, U: undefined), c) Distribution of the stress-shape, $\Phi=(\sigma_2-\sigma_3)/(\sigma_1-\sigma_3)$. Fault lines from Karakonstantis and Papadimitriou (2010) and Sakellariou and Tsampouraki-Kraounaki (2016).

The stress-field, and in particular the component of maximum horizontal compression, **S**$_{Hmax}$, was found in good agreement with the respective principal strain-rate axes determined by GPS/GNSS data, such as the Global Strain Rate Model (GSRM; Kreemer *et al.*, 2003). Some differences are observed in areas of low strain-rate magnitude, as, for example in NW Greece, near Corfu, where the stress-field suggests compression more transverse to the Apulian collision front than the strain-rate field implies, and SW Aegean, where the strain-rate tensor is overwhelmed by the contraction along the Hellenic Arc, whereas the stress-field is related to strike-slip faulting near Crete and N-S normal faulting in southern Peloponnese and near Rhodes Island.

To investigate the effects of the stress-field on the kinematics of known faults, the stress-tensor was applied on the fault-sources (FS) of the European Seismic Hazard Model 2013 (ESHM13; Woessner *et al.*, 2015). In most regions, our results were found to be compatible with the ESHM13 FS, in terms of orientation and expected faulting type (Fig. 2), which was examined by imposing the direction of maximum shear on the fault plane as the direction of slip. Some differences were observed in regions of low strain-rate, such as the southern Aegean, where left-lateral strike-slip E-W faulting is expected, in contrast to the registered E-W normal FS. Discrepancies were also found in areas with complex tectonics, such as pullapart basins in Western Greece, where the resolution of the regional stress-field is insufficient to explain local stress heterogeneities, or near the boundaries between regions with different tectonic regimes. Nevertheless, such areas were highlighted by anomalies in the stress-shape, Φ (Fig. 1c), which is strongly dependent on the variation of one principal stress axis while another remains relatively stable. A high Φ-value anomaly runs along the Andravida fault zone, which hosted the 8 June 2008 M_w=6.4 earthquake (e.g. Ganas *et al.*, 2009) and further north along the normal and strike-slip zones of Lake Trichonis (e.g. Kassaras *et al.*, 2014) and Amvrakikos gulfs. On the other hand, a low Φ-value, E-W oriented anomaly marks a significant rotation of the stress-field by 90° that occurs along the latitude=37°N, turning from E-W (in the north) to N-S (in the south) normal faulting in southern Peloponnese and Dodecanese Islands, as well as from dextral to sinistral SW-NE strike-slip faulting in northern and southern Aegean, respectively. The regional stress-tensor, which is available online at http://dx.doi.org/10.17632/sm8bj39nfy.1 (Kapetanidis & Kassaras, 2019b), can provide first-order knowledge that is useful for further studies involving focal mechanisms / fault kinematics, Coulomb stress transfer and seismic hazard assessment.

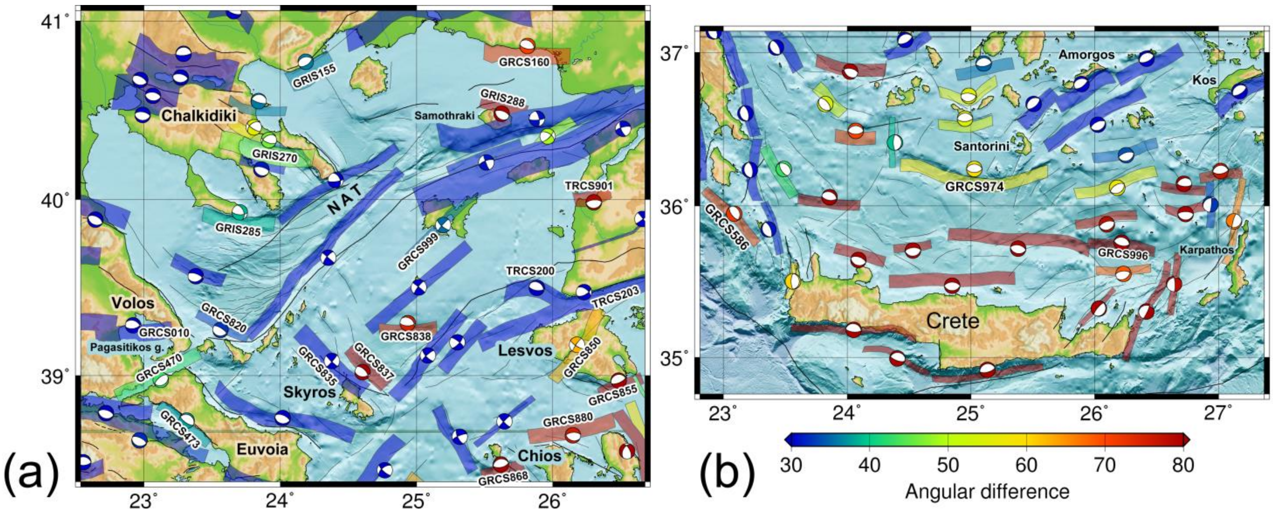

Figure 2. ESHM13 Fault Sources (polygons) with their kinematics represented by beachballs. Colors indicate the minimum angular difference between the orientation of the FS's "equivalent moment tensor" principal axes (P, N, T) and the respective axes (S_1, S_2, S_3) of the stress-tensor, a) in northern Aegean, b) in southern Aegean.

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